

# PINE-HARDWOOD REGENERATION IN SMALL OPENINGS FOR UNEVEN-AGED MANAGEMENT <sup>1</sup>

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**Abstract.** Uneven-aged management of pine-hardwood mixtures may prove acceptable for providing desirable combinations of timber and nontimber resources if these mixtures can be regenerated in small openings. Several combinations of opening size and degree of hardwood control were examined in a low-quality Piedmont hardwood stand. After one growing season, 80 percent of planted pines survived and most had doubled in height and remained free to grow. Hardwood regeneration was taller than pines in all treatments but was most vigorous in 1/3-ac openings where residual stems were felled and no herbicide was applied.

## Introduction

Pine-hardwood mixtures are gaining acceptance for improving the productivity of low-quality hardwood stands while maintaining other values such as aesthetics, wildlife habitat, and species diversity. Pine-hardwood regeneration should be attractive to private nonindustrial landowners because it is generally less expensive to obtain than pine (Phillips and Abercrombie 1987). In the Piedmont Plateau and Appalachian Mountains of the Southeastern United States, 26.8 million acres of commercial forest land are occupied by hardwood or mixed pine-hardwood stands (Bechtold and Ruark 1988). Private nonindustrial landowners who control 72 percent of these stands generally ignore opportunities to convert to pine because of the expense, objections to clearcutting, or preferences for nontimber re-

sources (Haymond 1988). Given limited options, most of these landowners choose to leave their woodlands unmanaged.

The USDA Forest Service is mandated by law to manage the National Forests to meet the goals of society as determined by the forest planning process. Under the New Perspectives Program, nontraditional forest management systems will be tried. Lower timber production will be accepted to favor other resources such as diversity, wildlife habitat, and aesthetics. Uneven-aged management is being tested on several National Forests and may become more common on others. Most research on uneven-aged management in the South has dealt with hardwood stands and with loblolly (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill.) stands. Uneven-aged management of pine-hardwood mixtures may be attractive for nonindustrial private and national forestland. However, supporting research is limited.

Single-tree selection has not proven successful for regenerating oaks and other desirable upland hardwood species of intermediate shade tolerance (Sander et al.,

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1983, Della-Bianca and Beck 1985). Group selection can be successful if there is adequate advance regeneration or small trees are felled for coppice (Sander 1988, Smith 1988). Development of hardwood regeneration is largely dependent on opening size, aspect, and site quality (Minkler and Woerheide 1965). Young hardwoods closer to the edge of openings than a distance equal to the height of border trees grow slower than those closer to the center. This pattern may be less pronounced on south-facing slopes which receive more direct and indirect sunlight (Minkler et al., 1973). Openings of ½- and 1-ac have proven satisfactory for plantings of red pine (*P. resinosa* Ait.), jack pine (*P. banksiana* Lamb.), and white pine (*P. strobus* L.) (Tubbs 1978). However, this technique has not been tested for southern pines or mixtures of pines and hardwoods.

The proportion of pine regeneration in a small opening in a hardwood or mixed pine-hardwood stand will likely depend on the pine species, the size of opening, and the degree of hardwood control. Loblolly pine seedlings are shade tolerant, but require more light as they get older (Brender 1973). Past research on regenerating pine-hardwood mixtures in clearcuts indicates that loblolly pine seedlings tolerate shade and other forms of competition on medium- to poor-quality sites. Most loblolly pine seedlings survive and overtop neighboring hardwood sprouts within 5 years (Waldrop et al., 1989; Evans 1990). These studies indicate that mixtures of upland hardwoods and loblolly pine may be regenerated successfully in small openings, particularly on medium to poor sites and on south-facing slopes.

This paper documents early results of an attempt to convert an uneven-aged low-quality Piedmont hardwood stand to an uneven-aged mixture of pines and hardwoods. Small openings were created throughout the stand to establish areas for management by group selection. Several opening sizes and levels of hardwood control were tried. Amounts of pine and hardwood regeneration present at the end of one growing season are reported here.

### Methods

In 1989, six treatment combinations were replicated three times in a randomized complete block design. Treatments included two opening sizes and three levels of hardwood control. Opening sizes of 1/3- and 1/10-ac were chosen because of the relationship of opening size to the height of border trees discussed by Minkler and Woerheide (1965). Circular openings of 1/3-ac have a diameter of approximately two tree heights (136 ft), while the diameter of 1/10-ac plots (74 ft) is approximately equal to one tree height. Levels of hardwood control included: (1) chainsaw felling of residual stems over 6-ft tall; (2) chainsaw felling of residual stems plus application of Garlon<sup>TM</sup> 3A to all stumps; and (3) no control. Replicates were blocked across the slope (upper, middle, and lower) to remove site differences. Analysis of variance and linear contrasts were used to test for treatment differences at the 0.05 level of confidence.

The study area is in the Upper Piedmont of South Carolina on a 27-ac tract of the Clemson University Experimental Forest in Pickens County. Slopes range from 6 to 10 percent with a uniform southwest exposure. Soils

are severely eroded clay loams of the Cecil series. These soils have poor fertility because past land management practices led to erosion of topsoil (USDA Soil Conservation Service 1972). Site index at age 50 years is 70 ft for loblolly pine and approximately 60 ft for upland oaks.

In 1989, this hardwood stand was all-aged with tree ages as high as 150 years, and there was a wide range of dbh classes. White oak (*Quercus alba* L.) was the most abundant overstory species, representing 41 percent of all stems and 30 percent of the basal area (Table 1). Other common overstory species were black oak (*Q. velutina* Lam.) and loblolly pine. Common understory species were dogwood (*Cornus florida* L.) and hickory (*Carya* sp.). Basal area was 73 ft<sup>2</sup>/ac in 1989.

Prior to 1974, the stand was an unmanaged oak-loblolly pine mixture with an average basal area of 100 ft<sup>2</sup>/ac (75 percent hardwoods and 25 percent pine). During that year, all pines of commercial size were harvested. Today, abundant natural regeneration of loblolly pine occurs throughout the stand in small openings created by the harvest. This regeneration may indicate that loblolly pine seedlings can survive in small openings where indirect sunlight is provided by a southwestern exposure. Study plots were located away from patches of heavy pine regeneration to minimize variation.

Prior to treatment installation, the diameters of all trees 2.5 inches dbh and larger were measured. Increment cores were extracted from a sample of 150 trees to examine age distribution. Sample trees were selected over the range of dbh classes and distributed throughout the stand. The relationship of age to dbh was determined with simple linear regression.

Trees were harvested on the 1/3- and 1/10-ac treatment plots in December 1989. All trees over 4.5 inches dbh were felled and limbed on site by research crews. Logs were skidded from the plots by a commercial logger in February 1990. To minimize damage to standing trees, skidder operators were requested to use logging roads and skid trails established for the 1974 harvest.

Hardwoods were controlled in early March 1990, immediately after logging. All residual stems over 6-ft tall were felled by chainsaw in 12 of the 18 study plots (two opening sizes x three control treatments x three replications). Garlon 3A was applied to all hardwood stumps in half of the plots where residuals were felled. The herbicide was applied at full strength with no water. Hardwood control was not attempted in the remaining six openings. In these plots, the basal area of residual stems averaged 10.8 ft<sup>2</sup>/ac. For all residual stems, horizontal crown spread was estimated by averaging the distance from the bole to the outer edge of the crown in each of the four cardinal directions. Crowns of residual stems covered an average of 30 percent of each opening. Genetically-improved loblolly pine seedlings were planted by research crews in each opening during the first week of March 1990 at a spacing of 12 x 12 ft.

The location of each planted pine was mapped to monitor the relationship of position within a plot to survival and growth. Each pine was tallied as alive or dead in all plots on the first day of each month from April through September 1990. Total seedling height and the height at last

Table 1. Mean number of stems and basal area per acre before harvest by species group and size class.

Species group	Stem dbh class (inches)			Total (percent)
	2.5-5.4	5.5-9.4	>9.4	
----- (stems/ac) -----				
Oaks				
White	56.3	11.6	14.6	82.5 (41)
Black	9.6	4.5	3.1	17.2 ( 9)
Scarlet	3.9	2.0	3.3	7.6 ( 4)
Post	1.8	2.6	4.2	8.7 ( 5)
Southern red	3.1	1.2	3.3	7.6 ( 4)
Misc.	0.1	0.1	0.0	0.3 (<1)
Total	<u>74.9</u>	<u>22.1</u>	<u>28.6</u>	<u>125.5 (63)</u>
Other hardwoods				
Yellow-poplar	1.5	0.6	1.2	3.3 ( 2)
Hickory	9.7	4.8	3.5	18.0 ( 9)
Dogwood	22.7	1.9	0.3	24.9 (12)
Misc.	10.8	2.3	0.4	13.6 ( 7)
Total	<u>44.7</u>	<u>9.6</u>	<u>5.4</u>	<u>59.8 (30)</u>
Pines				
Loblolly	2.6	5.9	4.3	12.9 ( 6)
Shortleaf	1.2	0.0	0.0	1.3 ( 1)
Virginia	0.1	0.1	0.0	0.3 (<1)
Total	<u>4.0</u>	<u>6.1</u>	<u>4.4</u>	<u>14.4 ( 7)</u>
All species	<u>123.7</u>	<u>37.8</u>	<u>38.3</u>	<u>199.8(100)</u>
Basal area (ft <sup>2</sup> /ac)				
Oaks				
White	1.3	3.4	17.2	21.9 (30)
Black	0.2	0.8	4.3	5.3 ( 7)
Scarlet	0.3	0.6	4.7	5.6 ( 8)
Post	0.2	0.8	4.3	5.3 ( 7)
Southern red	0.3	0.3	4.7	5.3 ( 7)
Misc.	0.0	0.0	0.1	0.1 (<1)
Total	<u>3.0</u>	<u>6.4</u>	<u>36.8</u>	<u>46.2 (63)</u>
Other hardwoods				
Yellow-poplar	0.1	0.2	2.2	2.5 ( 3)
Hickory	0.9	1.2	3.6	5.7 ( 8)
Dogwood	1.8	0.3	0.3	2.4 ( 3)
Misc.	1.0	4.8	1.6	7.3 ( 4)
Total	<u>3.8</u>	<u>6.5</u>	<u>7.7</u>	<u>17.9 (25)</u>
Pines				
Loblolly	0.3	1.9	4.1	6.3 ( 9)
Shortleaf	2.4	0.0	0.0	2.5 ( 3)
Virginia	0.0	0.0	0.0	0.1 (<1)
Total	<u>2.7</u>	<u>1.9</u>	<u>4.1</u>	<u>8.9 (12)</u>
All species	<u>9.5</u>	<u>14.8</u>	<u>48.7</u>	<u>73.0(100)</u>

year's node were measured at the end of the growing season. Growth was calculated as the difference between the two height measurements. During the September survey, the percentage of the crown of each seedling that was directly covered by nearby vegetation was estimated. Categories included 0, 1-25, 26-50, 51-75, and 76-100 percent covered. Seedlings were considered free to grow if no more than 75 percent of the crown was directly covered by competing vegetation and the terminal bud was not covered. Cover by residual stems over 6 ft tall was not included in estimates of direct cover.

Species composition and growth of hardwood regeneration were measured in September 1990. Circular sample plots, 0.001 ac in size, were established in a systematic pattern over each opening. A total of 50 sample plots was used in 1/3-ac openings, while 15 plots were used in 1/10-ac openings. Both samples represent 15 percent of the opening size. All seedlings and sprouts were tallied by species. Height was measured to the nearest 0.1 ft. In sprout clumps, all sprouts were counted, but height was measured only on the dominant sprout.

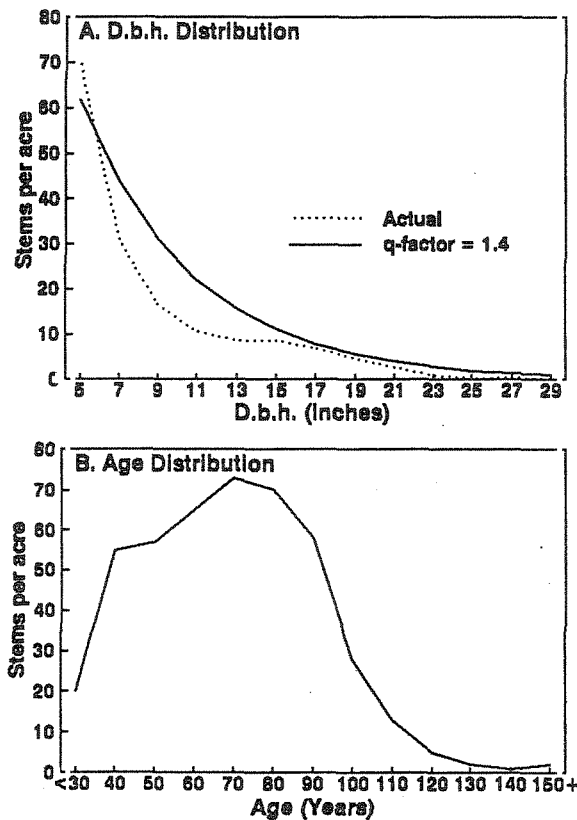


Figure 1. The dbh (a) and age (b) distributions of a Piedmont hardwood stand before harvest.

## Results And Discussion

The dbh distribution of the stand prior to harvest was a reverse-J pattern, with large numbers of small trees and fewer large trees (Fig. 1a). This distribution had a q-factor of approximately 1.4, which is within the range Smith (1986) described acceptable for managed uneven-aged stands. A condition that must be met when single-tree selection is based on diameter is that dbh is closely correlated with age. Otherwise, fast-growing young trees may be selected for harvest, resulting in high grading of the stand. In the study stand, dbh was not well correlated with age ( $R^2=0.42$ ). There were too few stems in age classes younger than 70 years (Fig. 1b). Under the observed conditions group selection may be a better choice than single-tree selection because trees of all dbh and age classes are harvested. Thinning of the residual stand, which would normally be done under group selection to create a reverse-J dbh distribution, was not necessary.

Natural regeneration of pines occurred infrequently. Survival of planted pines remained high throughout the first growing season for all opening sizes and levels of hardwood control. Survival at the end of the growing season was somewhat higher in 1/10-ac openings (86 percent) than in 1/3-ac openings (80 percent), but the difference was not statistically significant. Also, survival was not affected by level of hardwood control. At the beginning of May, all seedlings in 1/10-ac openings were alive but some mortality had occurred in 1/3-ac openings. This difference did not persist through later months, however.

Mortality of planted pines was greatest from early June through early August (Fig. 2), the driest period of the 1990 growing season. In 1/3-ac openings, seedling mortality was most common in the center and northwest quarter of study plots, which are the areas that received most direct sunlight. Mortality in 1/10-ac openings, which received less direct sunlight, was randomly scattered throughout the plot. These patterns may indicate that pine seedling mortality during the first growing season was associated with moisture stress rather than shading or other forms of competition.

Total height and growth of planted pines appeared to be greater in 1/3-ac openings than in 1/10-ac openings (Table 2), but differences were not significant. Seedling height growth averaged 0.64 ft in 1/3-ac openings and 0.56 ft in 1/10-ac openings. No differences due to level of hardwood control were observed. Approximately 70 percent of all surviving pines remained free to grow at the end of the first growing season (Table 2). Although the portion of free-to-grow pines was somewhat higher in 1/10-ac openings, differences between treatments were not significant.

Species composition of hardwood regeneration was somewhat different than that of the preharvest stand, but it did not vary among treatments (Table 3). Rather than white oak, which was dominant before harvest, regeneration consisted of even mixtures of sprouts of black oak, scarlet oak (*Q. coccinea* Muenchh.), white oak, black cherry (*Prunus serotina* Ehrh.), blackgum (*Nyssa sylvatica* Marsh.), dogwood, and hickory. Seedlings of yellow-poplar (*Liriodendron tulipifera* L.) were also abundant.

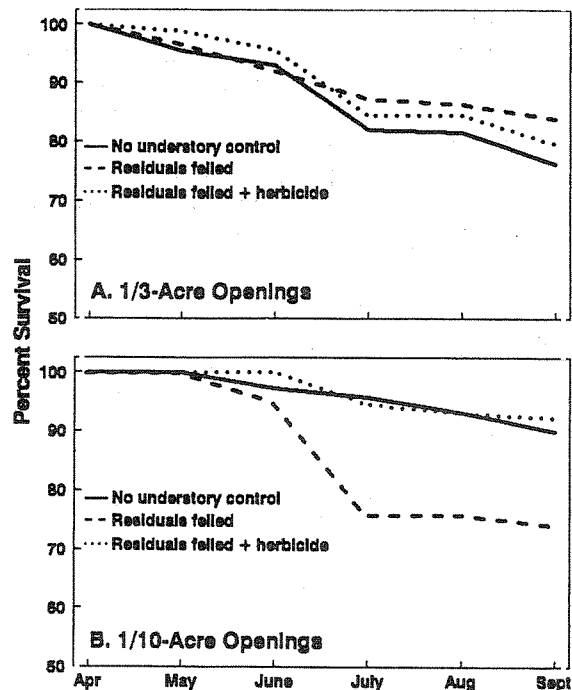


Figure 2. Mean monthly survival of planted pines by hardwood control treatment in 1/3-ac (a) and 1/10-ac (b) openings.

Table 2. Mean height, growth, and portion free-to-grow for planted pines surviving one growing season.

Treatment	Height	Growth	Free to grow
	----- ft -----		- percent -
1/10-ac openings			
No understory control	1.2	0.6	70.7
Residuals felled	1.0	0.6	78.1
Residuals felled + herbicide	1.1	0.6	68.3
1/3-ac openings			
No understory control	1.2	0.6	68.2
Residuals felled	1.2	0.7	69.0
Residuals felled + herbicide	1.3	0.7	67.7

Table 3. Species composition of hardwood regeneration by treatment.

Hardwood species	1/10-ac openings			1/3-ac openings		
	No control	Fell	Fell and herbicide	No control	Fell	Fell and herbicide
	----- (stems/ac) -----					
Black oak	57	177	247	191	107	183
Scarlet oak	130	190	177	210	160	209
White oak	263	127	300	327	244	544
Misc. oaks	23	20	14	0	7	17
Black cherry	70	137	127	194	138	176
Blackgum	63	0	147	174	244	161
Dogwood	403	233	117	311	912	546
Hickory	233	500	263	182	458	312
Yellow-poplar	212	329	103	43	113	153
Misc.	351	78	157	77	37	133
Total	1,340	1,420	1,680	2,177	2,690	2,406

Vigor of hardwood regeneration was affected by both opening size and level of understory control. For the oak and all-hardwood categories, the number of sprouts per cut stump was greater in 1/3-ac openings than in 1/10-ac openings (Table 4). Within the 1/3-ac openings, sprouts per stump were most numerous where residuals were felled but no herbicide was applied. In plots where residuals were not felled, sprouts originated from

the stumps of the trees of commercial size which were harvested. These stumps were from older trees and had less sprouting capabilities than stumps of felled residuals. In plots where residual stems were felled and herbicide was applied, the herbicide did not kill the entire stump and root system, but did reduce the number of sprouts produced. This pattern agrees with the results of Lewis et al. (1984), who found that a winter application of Garlon 3A to the stumps of Piedmont hardwoods killed only a portion of the stumps but effectively controlled sprout growth. Although supporting data were not collected, sprouts in plots where herbicide was applied appeared to be of better form than those in areas where herbicide was not applied. These sprouts tended to originate from below-ground buds while those in other areas originated from the above-ground cambium.

Table 4. Mean number of sprouts per stump by treatment and species group.

Treatment	Oaks	Other hardwoods	All hardwoods
	----- (number) -----		
1/10-ac openings			
No understory control	1.2a <sup>1</sup>	2.5a	1.9a
Residuals felled	1.7a	2.4a	2.0a
Residuals felled + herbicide	1.8a	1.7a	1.7a
1/3-ac openings			
No understory control	2.2ab	2.3a	2.3a
Residuals felled	3.3 b	4.0 b	3.7 b
Residuals felled + herbicide	2.4ab	2.7ab	2.4a

<sup>1</sup> Means within a column followed by the same letter are not significantly different at the 0.05 level.

Height of the dominant sprout in each clump was also affected by opening size and level of hardwood control (Table 5). Sprouts tended to be taller in 1/3-ac openings than in smaller plots because a larger portion of the hardwood regeneration was unaffected by competition from border trees. The difference was significant for the other hardwood and all-hardwood species groupings. This finding agrees with that of Minkler and Woerheide (1965) who showed that the vigor of hardwood regeneration increased with distance from the edge of the opening.

For all treatment combinations, hardwood sprouts were taller (Table 5) than the mean height of planted pines (Table 2). This difference was greatest in 1/3-ac openings where residuals stems were felled and herbicide was not applied. Within the all-hardwoods category, sprouts in these



Table 5. Mean height of the dominant sprout per clump by treatment and species group.

Treatment	Oaks	Other hardwoods	All hardwoods
	----- (ft) -----		
1/10-ac openings			
No understory control	1.1 a <sup>1</sup>	1.8 a	1.4 a
Residuals felled	1.6 a	1.9 a	1.8 a
Residuals felled + herbicide	1.3 a	1.7 a	1.5 a
1/3-ac openings			
No understory control	1.5 a	1.9 a	1.8 a
Residuals felled	2.1 a	2.6 b	2.5 b
Residuals felled + herbicide	1.8 a	2.0 ab	1.8 a

<sup>1</sup> Means within a column followed by the same letter are not significantly different at the 0.05 level.

treatment areas were significantly taller than for all other treatment combinations (Table 5). Sprouts in these areas originated from small, vigorous trees and were not affected by herbicide application; many were not affected by competition from border trees.

### Conclusions

At the end of one growing season, pine-hardwood regeneration appears to be successful in small openings which were created to allow a low-quality Piedmont hardwood stand to be managed by group selection. Survival of planted loblolly pine seedlings was over 80 percent, and approximately 70 percent of surviving seedlings remained free to grow. Pine mortality during the 1st year appeared to be associated with moisture stress rather than from shading or other forms of competition. Even though hardwood regeneration was taller than planted pines, surviving pines doubled in height. Numerous sprouts and seedlings of oak and other desirable hardwood species became established in each treatment area.

For pines to continue to survive and grow among hardwood regeneration, a balance of hardwood control and available sunlight is needed. The larger 1/3-ac openings provided more sunlight for the moderately intolerant pines, but hardwood regeneration overtopped pines where residuals were felled and no herbicide was used. Hardwood vigor was reduced in the smaller 1/10-ac openings and where residual stems were not felled. However, the increased shading typical of these treatments may prevent rapid pine growth. The combination of large openings to provide adequate sunlight and herbicide to control hardwood growth may prove most successful for establishing a pine-hardwood mixture.

Study plots will be observed for a number of years to evaluate the best combination of opening size and level of hardwood control. As pine and hardwood regeneration grows, direct competition between species groups will increase. The dynamics of young pine-hardwood mixtures are not well documented. Recent studies in clearcut areas with similar site quality (medium to poor) and aspect (southwest) indicate that pines will survive and over top the hardwood regeneration. However, competition from border trees increases the difficulty of predicting pine and hardwood survival and growth and requires additional study.

#### Literature Cited

- Bechtold, William A.; Ruark, Gregory A. 1988. Structure of pine stands in the Southeast. Res. Pap. SE-274. Asheville, NC: U.S. Department of Agriculture, Southeastern Forest Experiment Station. 185 p.
- Brender, Ernst V. 1973. Silviculture of loblolly pine in the Georgia Piedmont. Report No. 33. Macon, GA: Georgia Forest Research Council. 74 p.
- Della-Bianca, Lino; Beck, Donald E. 1985. Selection management in Southern Appalachian hardwoods. Southern Journal of Applied Forestry 9(3):191-196.
- Evans, Timothy L. 1990. Effects of fell-and-burn site preparation on wildlife habitat and small mammals in the upper Piedmont of Georgia and South Carolina. Clemson, SC: Clemson University. 52 p. Thesis.
- Haymond, Jacqueline L. 1988. NIPF opinion leaders: what do they want? Journal of Forestry 86(4):30-34.
- Lewis, J.B.; Zedaker, S.M.; Smith, D. Wm. 1984. Control of stump sprouting in Piedmont hardwoods. p. 182-191. In: Proceedings, Southern Weed Science Society 37th Annual Meeting Biotechnology and Weed Science. 1984 January 17-19; Hot Springs, AR.
- Phillips, Douglas R.; Abercrombie, James A., Jr. 1987. Pine-hardwood mixtures: a new concept in regeneration. Southern Journal of Applied Forestry 11(4):192-197.
- Minkler, Leon S.; Woerheide, John D. 1965. Reproduction of hardwoods 10 years after clearcutting as affected by site and opening size. Journal of Forestry 63:103-107.
- Minkler, Leon S.; Woerheide, John D.; Schlesinger, Richard C. 1973. Light, soil moisture, and tree reproduction in hardwood forest openings. Res. Paper NC-89. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

- Sander, Ivan L. 1988. Guidelines for regenerating Appalachian oak stands. p. 189-198. In: Smith, H. Clay; Perkey, Arlyn W.; Kidd, William E., Jr. (eds); Proceedings, Guidelines for Regenerating Appalachian Hardwood Stands. 1988 May 24-26; Morgantown, WV. 293 p.
- Sander, Ivan L.; McGee, Charles E.; Day, D.G.; Willard, R.E. 1983. Oak-hickory. p. 116-120. In: Burns, Russell M. (tech. comp.); Silvicultural Systems for The Major Forest Types of The United States. Agricultural Handbook 445. Washington D.C.: U.S. Department of Agriculture. 191 p.
- Smith, David M. 1986. The Practice of Silviculture. Eighth edition. New York: John Wiley and Sons. 527 p.
- Smith, David W. 1988. Uneven-aged regeneration in Appalachian hardwoods. p. 131-147. In: Smith, H. Clay; Perkey, Arlyn W.; Kidd, William E., Jr. (eds.); Proceedings, Guidelines for Regenerating Appalachian Hardwood Stands. 1988 May 24-26; Morgantown, WV. 293 p.
- Tubbs, Carl H. 1978. Stand composition in relation to uneven-aged silviculture. p. 88-103. In: Proceedings, uneven-aged silviculture and management in the United States. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Timber Management Research. 234 p.
- USDA Soil Conservation Service. 1972. Soil Survey of Pickens County, South Carolina. Washington, D.C.: U.S. Department of Agriculture, Soil Conservation Service. 70 p.
- Waldrop, Thomas A.; Lloyd, F. Thomas; Abercrombie, James A., Jr. 1989. Fell and burn to regenerate mixed pine-hardwood stands: an overview of research on stand development. p. 75-82. In Waldrop, Thomas A. (ed.); Proceedings of Pine-hardwood Mixtures: A Symposium on Management And Ecology of The Type; 1989 April 18-19; Atlanta, GA: Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 271 p.

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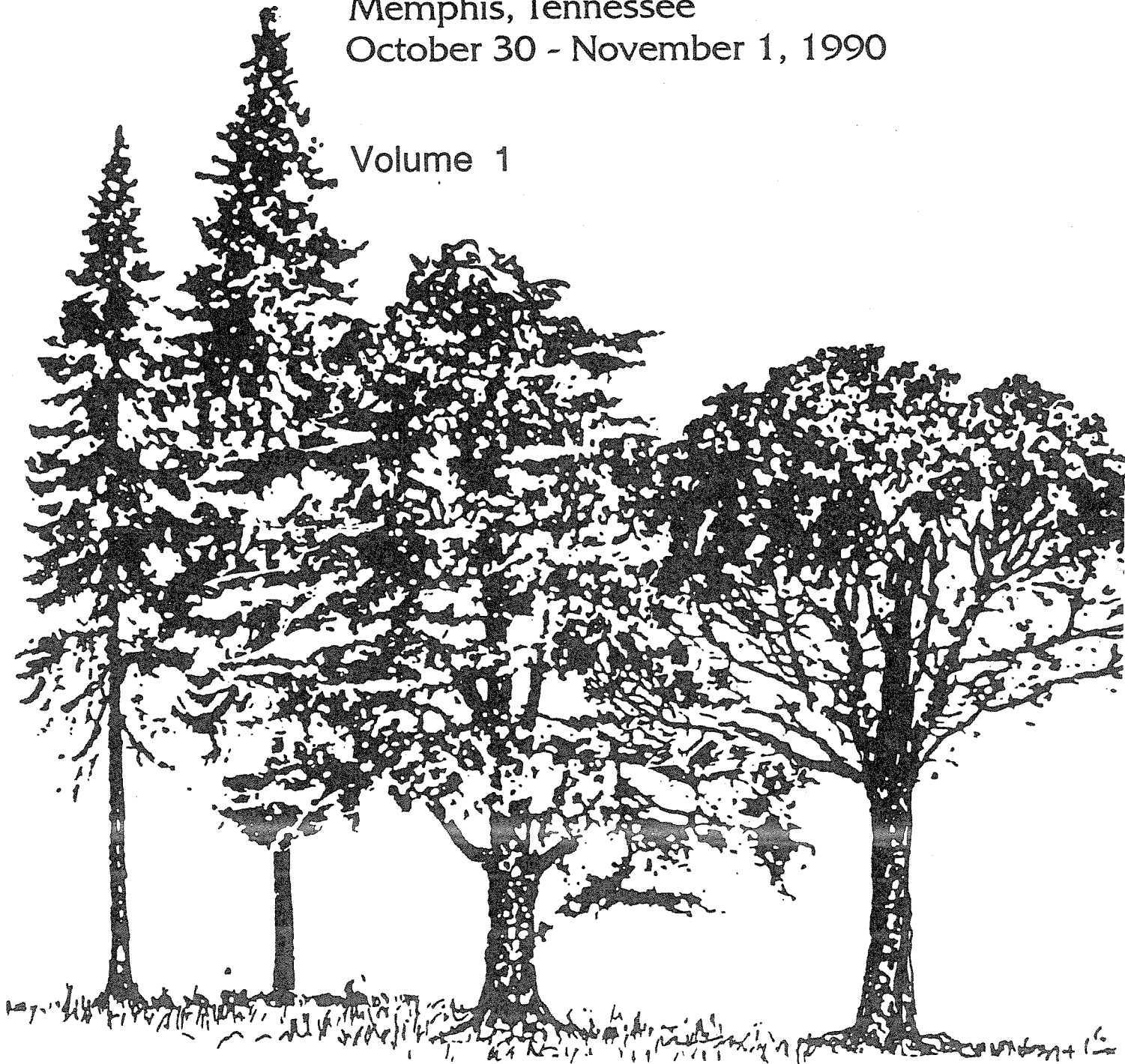
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# Proceedings of the **Sixth Biennial Southern Silvicultural Research Conference**

Memphis, Tennessee

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Volume 1



## PREFACE

This document presents research investigations of 256 scientific professionals studying patterns and processes of managed southern forests through 95 reported studies. These contributions emanate from formal researchers, extension, and staff specialists, and forest managers. Authors represent a cross section of universities, forestry and horticultural companies, and public agencies. Their approaches and findings are worthy of study and, where appropriate, incorporation into the logical system we call silvicultural literature.

Three invited general session presenters addressed the challenges to forestry in the South from the viewpoints of federal, industrial, and nonindustrial private forest managers.

An exciting field tour to the Ames Plantation on the third day of the conference was hosted by the Ames Foundation and the University of Tennessee. Those attending expressed appreciation for the opportunity to observe the forest and wildlife research and demonstration sites on the Plantation.

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Dean Gjerstad, Auburn University, Auburn, AL

Dave Smith, Virginia Polytechnic Institute and State University, Blacksburg, VA

John Pitcher, Hardwood Research Council, Memphis, TN

The diligence and thoroughness of these individuals are to be commended. Special recognition is also offered to the superb panel of distinguished moderators that led each session.

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Daniel G. Neary  
Program Chairperson  
Southeastern Forest Experiment Station

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